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Performance Enhancement of Micro strip Patch Antenna Using Metamaterial

G.Pradeep [1], Dr.N.Gunasekaran[2]
[1]PG Scholar, Department of ECE, Rajalakshmi Engineering College, Chennai, INDIA
[2]Dean & Professor, Department of ECE, Rajalakshmi Engineering College, Chennai, INDIA

Abstract- **Antenna is a transducer which converts electrical signal into electromagnetic waves and it radiates into free space. Micro strip patch antenna has advantage of low profile configuration, light weight and low fabrication cost. But it has major drawback of lower gain and narrow band. The drawback of microstrip patch antenna is overcome by using metamaterial. The proposed antenna is designed for the operating frequency of 2GHz and is designed on FR4 substrate. Metamaterial is used to improve the performance of patch antenna. The metamaterials are artificial materials characterized by parameters generally not found in nature, but can be engineered. They differ from other materials due to the negative permittivity and negative permeability properties. The split ring resonator (SRR) and complementary split ring resonator (CSRR) are the structure of metamaterials.In the proposed method, the metamaterial structures are used on the patch, substrate and ground plane. The configurations are simulated and analyzed using High Frequency Structure Simulator (HFSS) software. The metamaterial antenna gives an improved Bandwidth of 145MHz (7%) when compared to Bandwidth of 71.1MHz (3.5%).**

Keywords — DNG, Metamaterial, Microstrip Patch Antenna, SRR, CSRR, HFSS software.

I.INTRODUCTION

The antenna or aerial is defined as "a means of radiating or receiving radio waves"[1]. Designing of antenna for high frequency and other applications has become a tremendous improvement in the mobile manufacturing industries. Today the advancement in antenna design rises up to 4G and beyond. Small size, light weight, compact structure, low profile, robustness and flexibility are the prime considerations conventionally taken into account in small antenna design. A microstrip antenna contains very extensive applications in recent times which exhibit the above mentioned qualities. However, patch antennas have a main disadvantage: narrow bandwidth and low gain. Most of techniques are used to overcome the drawback of microstrip patch antenna. Here the new concept called "Metamaterial" is used to improve the performance of patch antenna such as bandwidth, gain, return loss and radiation pattern.

II.CONVENTIONAL PATCH ANTENNA

An antenna is a part of transmitting or receiving system that is designed to radiate or to receive electromagnetic waves". For an antenna to be efficient, it must have a physical extent that is at least an appreciable fraction of a wavelength at the operating frequency.

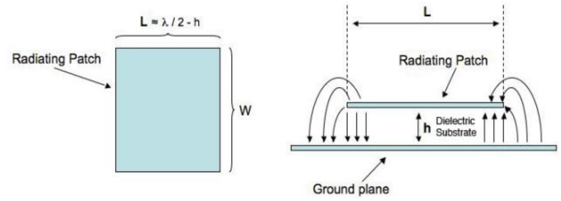


Figure 1. Patch antenna

The figure1 shows a patch antenna consists of a flat plate over a ground plane. The center conductor of a coax serves as the feed probe to couple electromagnetic energy in and/or out of the rectangular microstrip patch antenna.

The electric field is zero at the center of the patch, maximum (positive) at one side, and minimum (negative) on the opposite side. It should be mentioned that the minimum and maximum continuously change side according to the instantaneous phase of the applied signal. The electric field does not stop abruptly at the patch's periphery as in a cavity; rather, the fields extend the outer periphery to some degree. These field extensions are known as fringing fields and cause the patch to radiate.

III.METAMATERIALS

Metamaterials [2] are artificial structures that can be designed to exhibit specific electromagnetic properties not commonly found in nature. Recently, metamaterials with simultaneously negative permittivity (ε) and permeability (μ), more commonly referred to as left-handed (LH) materials, have received substantial attention in the scientific and engineering communities.Metamaterial antenna are a class of antennas which use metamaterials to increase performance of miniaturized antenna systems and improve the performance of the antenna.

Their purpose, as with any electromagnetic antenna, is to launch energy into free space. However, this class of antenna incorporates metamaterials, which are materials engineered with novel, often microscopic, structures to produce unusual physical properties. Antenna designs incorporating metamaterials can step-up the antenna's radiated power.

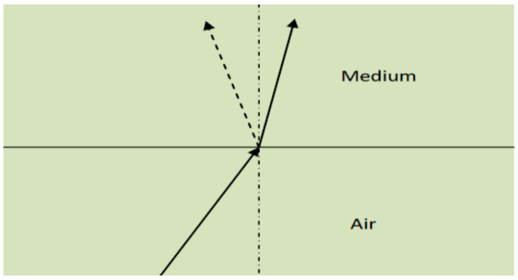


Figure 2. Conventional (solid) and metamaterial (dotted) refraction characteristics

Some applications for metamaterial antennas are wireless communication, space communications, GPS, satellites, space vehicle navigation and airplanes.

Surface wave propagation is a major problem in patch antennas that reduces antenna gain and efficiency, increases cross polarization, limits the bandwidth, increases end fire radiation, limits the applicable frequency range and hinders the miniaturization of patch antenna. Micromachining technology and photonic band gap structures are two solutions to the surface wave problem. This is also reversal of Doppler Effect or reversal of snells law.

Type of metamaterial structure

- Split Ring structure
- Symmetrical Ring structure
- Omega structure
- S structure
- Electromagnetic Band Gap Structure
- Artificial Magnetic Conductor
- Photonic Band Gap

Split Ring Resonator

Split Ring Resonator [3] is mostly used metamaterial structure to improve the performance of the patch. Split ring resonator is two metallic rings arranged in opposite direction with opposite splits.

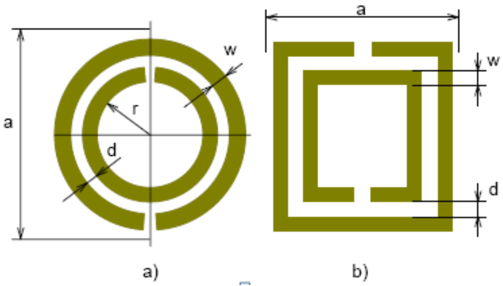
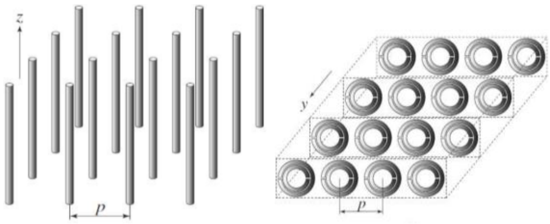


Figure 3. Split Ring Resonator
(a)Circular Structure (b) Square Structure

The negative-ε/positive-μ MTM is the metal thin-wire (TW) structure, Fig 4.3(a). If the excitation electric field **E** is parallel to the axis of the wires (**E**_z), so as to induce a current along them and generate equivalent electric dipole moments, this MTM exhibit a plasmonic-type permittivity frequency function.

The positive-ε/negative-μ MTM is the metal split-ring resonator (SRR) structure, Fig 4.3(b). If the excitation magnetic field **H** is perpendicular to the plane of the rings (**H**⊥y), so as to induce resonating currents in the loop and generate equivalent magnetic dipole moments, this MTM exhibits a plasmonic-type permeability frequency function.



(a) (b)
Figure 4. (a)Thin wire (b) Split ring resonator

Complementary Split Ring Resonator

CSRR [4] is composed of two concentric metallic ring slots with slits etched in each ring at its opposite sides. The CSRR is loaded on the patch or the ground plane to improve the performance of the rectangular microstrip patch antenna.

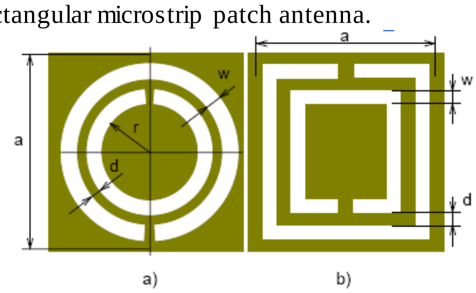


Figure 5. Complementary Split Ring Resonator
(a)Circular Structure (b) Square Structure

The plasma frequency for the patch is given by,

$$\omega_p^2 = \frac{2\pi c^2}{a^2 \ln(a/r)}$$

The dielectric constant or permittivity is given by,

$$\varepsilon_{eff} = 1 - \frac{\omega_p^2}{\omega[\omega - i(\omega_p^2 a^2 \varepsilon_o)/\sigma\pi r^2]}$$

The permeability is given by,

$$\mu_{eff} = 1 - \frac{\pi r^2/a}{1 + \frac{2\sigma i}{\omega r \mu_o} - \frac{3d}{\pi^2 \mu_o \omega^2 \varepsilon_o \varepsilon r^3}}$$

Types of Split Ring Resonator

- Edge coupled SRR (EC-SRR)
- Broadside-couple SRR (BC-SRR)
- Nonbianistropic SRR (NB-SRR)
- Double-Split SRR(DS-SRR)
- Spiral SRR (S-SRR)
- Open split ring resonator (O-SRR)

- H-Shaped split ring resonator (HS-SRR)

IV.LITERATURE SURVEY

J. B. Pendry, A. J. Holden, D. J. Robbins, and W. J. Stewart, **"Magnetism from Conductors and Enhanced Nonlinear Phenomena**", describes the theory of non magnetic conducting sheet exhibits an effective permeability. This paper also describes the effect of metallic rod and split rings on the patch or conducting medium.

Varsha Gupta, Pooja Sahoo, "**Performance Improvement of Microstrip Patch Antenna"**, presents a planar metamaterial antenna structure which provides normal patch antenna performance with low return loss. The return loss of the structure can be increased up to - 25dB.

Anisha Susan Thomas, Prof. A K Prakash "**A Survey on Microstrip Patch Antenna**", describes the performance parameters such as bandwidth, gain of patch antennas which are usually considered as narrowband antennas.

Atul Kumar, Nithin Kumar and Dr.S.C. Gupta, "**Review on microstrip patch antenna using Metamaterial**", describes the structure of metamaterial such as Split Ring Resonator (SRR) and Complementary SRR (CSRR) are used for improve the performance of patch antenna.

Vikas Gupta and B.S.Dhaliwal, "**Performance enhancement of rectangular microstrip patch antenna loading complementary split ring resonator in the patch**", describes the complementary split ring resonator is used to improve the gain, bandwidth, return loss and directivity.

H.Nornikman, B.H.Ahmad, " **Effect of single complementary split ring resonator structure on microstrip patch antenna design**", describes the CSRR on the ground plane for different positions are analyzed.

Shridhar E. Mendhe & Yogeshwar Prasad Kosta, "**Metamaterial Properties and Applications**" discusses the properties and applications of patch antenna. It also describes that patch metamaterial are engineered media whose electromagnetic responses are different from those of their components.

V.PROPOSED METHOD

DESIGN STEPS FOR PATCH ANTENNA

The design steps are referred by Balanis are given by

1. Operating Frequency, $f_o = 2GHz$
2. The substrate material used is FR4.
   Dielectric constant, $\varepsilon_r = 4.4$
3. Height of the substrate, h = 1.6mm
4. Wavelength of the frequency:
   $\lambda = \frac{c}{f} = 150mm$
5. Effective dielectric constant:
   $\varepsilon_{eff} = \frac{\varepsilon r+1}{2} + \frac{\varepsilon r-1}{2}[1+\frac{12h}{W}]^{-0.5} = 4.1260$
6. Width of the patch:
   $W = \frac{c}{2fr}\sqrt{\frac{2}{\varepsilon r+1}} = 45.6mm$
7. Length extension,
   $\Delta l = 0.412h\ [\frac{4.1260+0.3}{4.1260-0.258}][\frac{W/h+0.264}{W/h+0.8}] = 0.7404\ mm$
8. Effective length:
   $L_{eff} = \frac{c}{2fo\sqrt{\varepsilon eff}} = 36.9mm$
9. Actual length of patch:
   $L = L_{eff} - 2\,\Delta l = 35.44mm$
10. Design of ground plane and substrate:
    $L_g = 6h+L = 45.04\ mm$
    $W_g = 6h+W = 55.2\ mm$
11. Coaxial cable:
    Inner coax = 0.5 mm
    Outer coax = 2 mm
12. Air box:
    Height of the air box = $\frac{\lambda}{4} = \frac{70.88}{4} = 17.72mm$

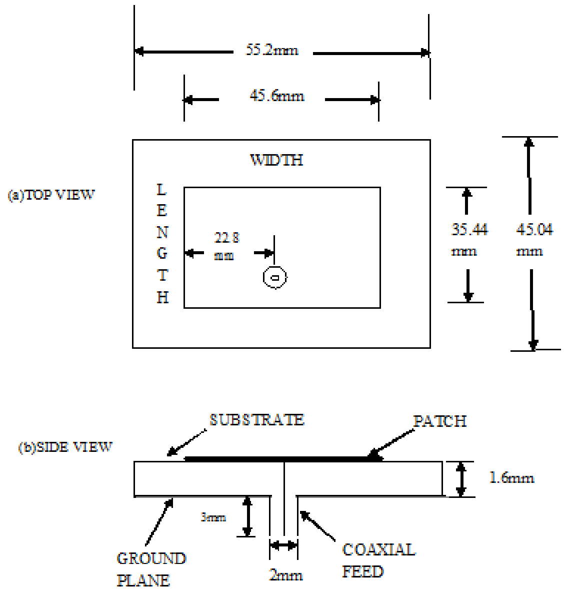
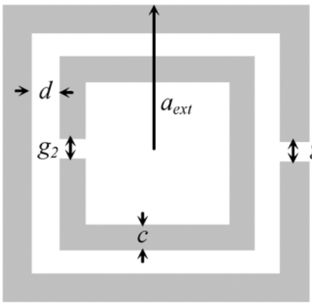


Figure (a)Top view of an Antenna
(b)Side view of an Antenna

Figure 6. Conventional patch antenna

DESIGN OF METAMATERIAL (UNIT CELL) SRR



a_{ext}	2.5
c	0.35
d	0.6
$g_1 = g_2 = g$	0.7

Figure 7. SRR and its dimension

In proposed method the conventional patch antenna are compared with metamaterial loaded antenna. And the performance is analyzed. In this paper the periodic array or structure of split ring resonator and Complementary Split Ring Resonator are embedded on the substrate and patch.

The metamaterial loaded antenna gives the better performance compare with the conventional path antenna. The Return loss, bandwidth, VSWR and radiation pattern are observed for the metamaterial loaded antenna.

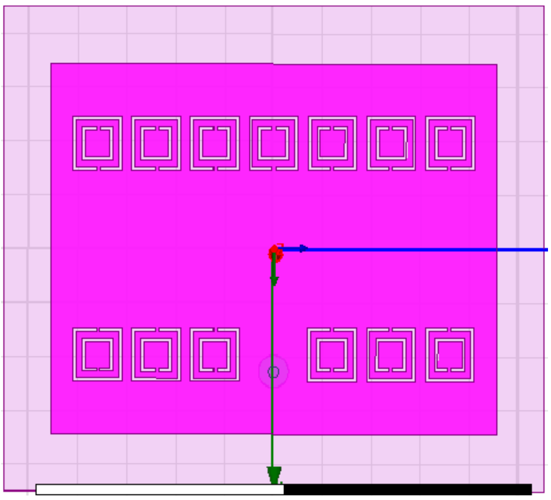


Figure 8. The proposed metamaterial antenna (CSRR on the patch)

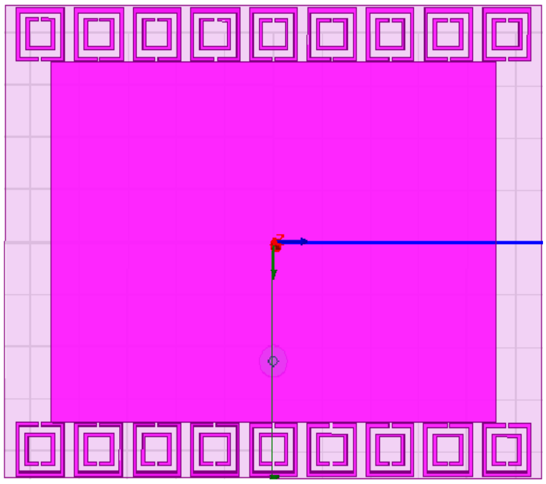


Figure 9. The proposed metamaterial antenna (SRR on the substrate)

VI.RESULTS AND DISCUSSION

The result of conventional patch antenna and proposed metamaterial patch antenna are analyzed and the parameters such as return loss, VSWR, Radiation pattern and Smith chart are noted.

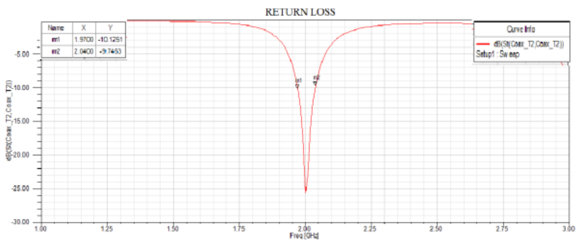


Figure 10. Return loss of conventional patch antenna

The figure 10 shows the Bandwidth of 67.5MHz (3.5%) and the return loss of -26.567dB for the patch antenna.

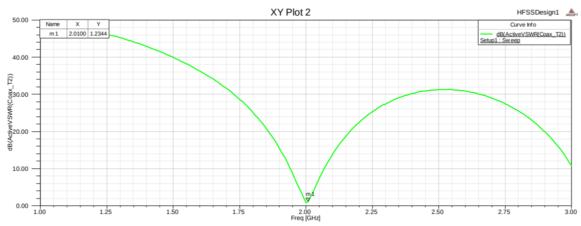


Figure 11. VSWR of the conventional patch antenna

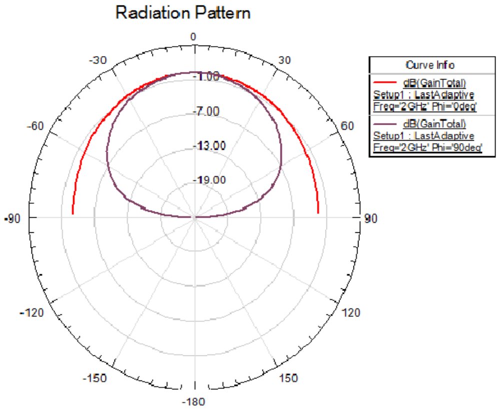


Figure 12. Radiation pattern of conventional patch antenna

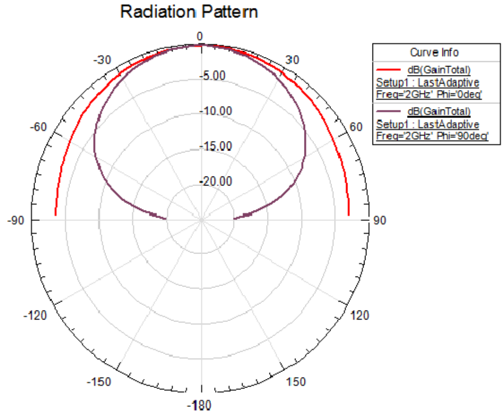


Figure 16. Radiation pattern of the metamaterial patch antenna

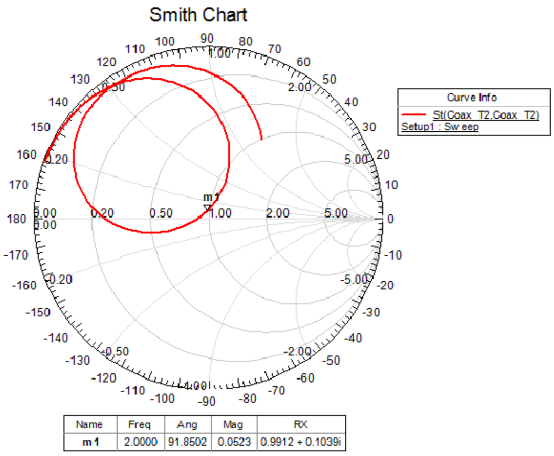


Figure 13. Smith chart of the Conventional patch antenna

The input impedance of patch antenna is normalized to 50Ω .

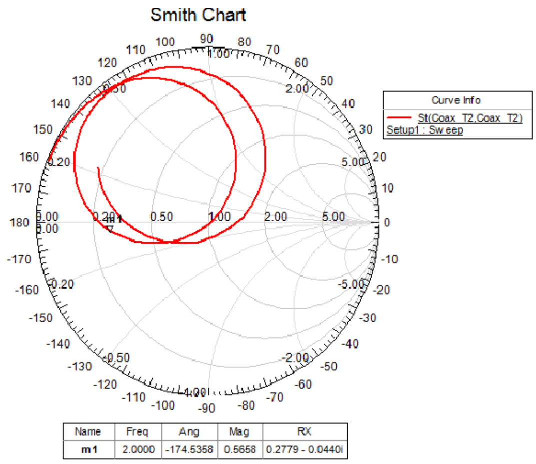


Figure 17. Smith chart of the metamaterial antenna

Figure 17 shows the input impedance is normalized to 50Ω for the metamaterial antenna.

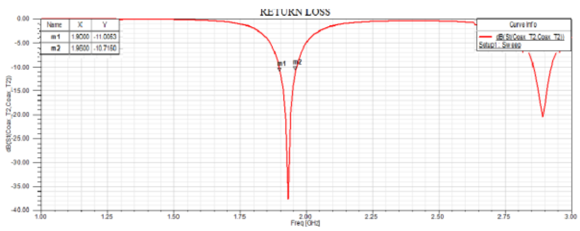


Figure 14. Return loss of proposed patch antenna. (CSRR on the patch)

Figure 14 shows the Bandwidth of 79.7MHz (4.5%) and the return loss of -35.567dB for the metamaterial patch antenna.

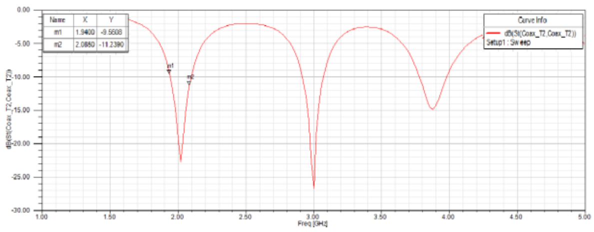


Figure 18. Return loss of the proposed antenna (SRR on the substrate)

Figure 18 shows the Bandwidth of 145.7MHz (7%) and the return loss of -27.567dB for the metamaterial patch antenna.

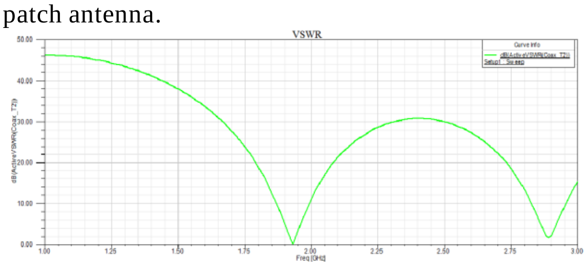


Figure 15. VSWR of the metamaterial patch antenna

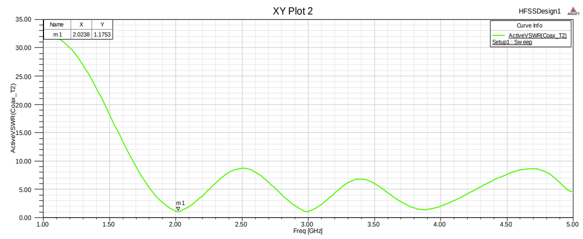


Figure 19. VSWR of the metamaterial patch antenna

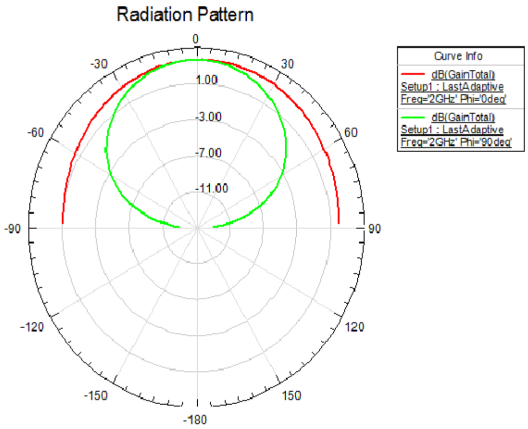


Figure 20. Radiation pattern of the metamaterial patch antenna

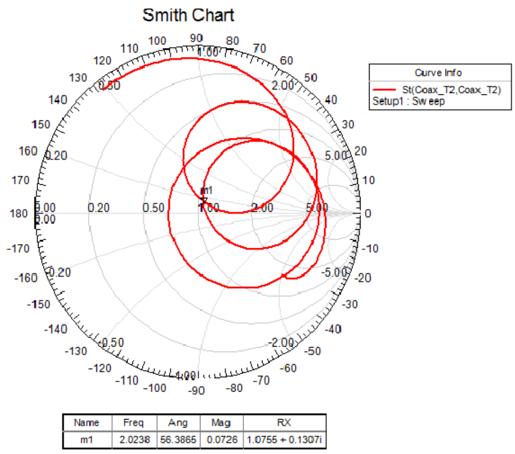


Figure 21. Smith chart of the metamaterial antenna

Figure 21 shows the input impedance is normalized to 50Ω for the metamaterial antenna.

VII.CONCLUSION

The performance of Conventional patch antenna is improved by using Metamaterial. The SRR and CSRR on the patch, Substrate and ground plane are analyzed using HFSS.The Metamaterial used antenna gives the Bandwidth of 145.7MHz (7%).It is more than the conventional patch antenna.

REFERENCES

[1] Balanis, Constantine, "Antenna Theory-Analysis and Design", John Wiley & Sons Ltd, Reprinted 1997.

[2] J. B. Pendry, A. J. Holden, D. J. Robbins, and W. J. Stewart, "Magnetism from Conductors and Enhanced Nonlinear Phenomena", IEEE Transactions on Microwave Theory and Techniques, Vol. 47, No. 11, November 1999.

[3] Vikas Gupta and B.S.Dhaliwal, "Performance Enhancement of Rectangular Microstrip Patch Antenna Loading Complementary Split Ring Resonator in The Patch", International Journal Of Electronics Engineering, Noida, 2012

[4] Atul Kumar, Nithin Kumar And Dr.S.C. Gupta, "Review On Microstrip Patch Antenna Using Metamaterial", International Journal Of Engineering Research And General Science Volume 2, Issue 4, June-July, 2014.

[5] H.Nornikman, B.H.Ahmad, "Effect Of Single Complementary Split Ring Resonator Structure On Microstrip Patch Antenna Design", Ieee Symposium On Wireless Technology And Applications (Iswta), Bandung, Indonesia, 2012.